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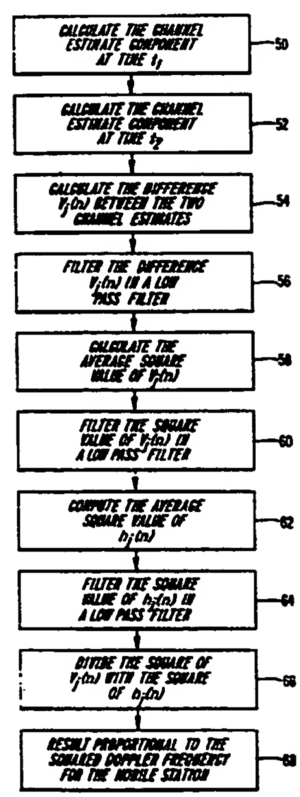
(54) Title: METHOD AND APPARATUS FOR ESTIMATING THE DOPPLER FREQUENCY OF A MOBILE STATION

(57) Abstract

A method and apparatus for approximating the doppler frequency of a mobile station (M1-M9) by examining the signal between the mobile station (M1-M9) and a base station (B1-B10). Several channel estimates ($h_j(n)$) are calculated at different intervals (t1, t2) for the signal between the mobile station (M1-M9) and the base station (B1-B10). The difference ($V_j(n)$) between these channels estimates ($h_j(n)$) is used to determine the approximate doppler frequency of the mobile station (M1-M9). A cellular mobile radio system can use the doppler frequency of the mobile station (M1-M9) to prioritize a handoff queue or to select an appropriate detecting algorithm for detecting data in a received signal (r(t)).



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Method and apparatus for estimating the Doppler frequency of a mobile station.

Field of the Invention

The present invention relates generally to cellular mobile radio systems having channels for transmitting information between base stations and mobile stations. More precisely, the invention relates to a method and apparatus for estimating the doppler frequency of a mobile station.

Background of the Invention

In cellular mobile radio systems, it is fundamental that a mobile station with an established connection on a radio channel shall be able to maintain the established connection when moving from one cell to another cell wherein the cells are serviced by different or the same base station. It is also highly desirable that the mobile station with an established connection on a radio channel shall be able to maintain the established connection on the radio channel shall be able to maintain the established connection when moving within the same cell and when the radio channel which is used is subject to increased interference. A process by which a mobile station can maintain an established connection when moving in a cellular radio system is generally called a handoff.

As the capacity demands on a cellular mobile radio system increase, it becomes increasingly important to be able to determine the speed of a mobile station when processing data received from the mobile station or when handling request for handoff. In a mobile cellular system which sets up a queue for mobile stations waiting to make a handoff to a free channel, problems arise when the speed of the mobile station is not taken into account in determining which mobile station receives the first available free channel. For instance, two mobile stations may be waiting in a handoff queue for a free channel to become available. The first mobile station may be traveling very fast and the second mobile station may be moving very slow. If the

second mobile station has requested a handoff before the first mobile station has requested a handoff, the second mobile station will be given the first available free channel even though the signal strength between the base station and the first mobile station is rapidly decreasing. As a result, the first mobile station may lose its signal entirely breaking the call before it ever receives an available channel. This problem will only increase as the size of the individual cells decrease and the capacity of the system increases.

In a mobile telephone system, the variations in a received signals phase and strength is due to the movement of the mobile station. Short term variations depend upon multipath propagation and is called short term fading, multipath fading or just fading. The maximum frequency of the fading is called doppler frequency and is proportional to the velocity of the mobile station. Another variation in a received signals phase and strength is long term variations due to the change in the propagation lose between the mobile station and the base station. The rate of the variation also depends upon the speed of the mobile station, e.g., the doppler frequency.

In cellular mobile radio systems, detecting algorithms are used to detect data in a signal received from a mobile station. However, some detecting algorithms work better for slow moving mobiles while other detecting algorithms work better for fast moving mobile stations. In most prior art systems, the systems uses detecting algorithms that usually optimize a received signal from a fast moving mobile station. As a result, a non-optimum solution results for slow moving mobile stations.

Summary of the Invention

The present invention overcomes the shortcomings of the prior art by taking into account the speed of a mobile station during a call handoff and when detecting data in a received signal. In the present invention, the speed of a mobile station is determined when the mobile station requests a handoff. As a result,

a handoff queue can be prioritized according to the speed of the mobile station. For example, a fast moving mobile station will be given a higher priority than a slow moving mobile station. As a result, the faster moving mobile stations, which are losing their signals faster than the slower moving mobile stations, receive the first available free channels. As a result, fewer mobile stations will lose their calls.

In addition, the speed of a mobile station can be used when deciding which detecting algorithm should be used for detecting data in a received signal. As a result, the cellular mobile radio system can select detecting algorithms which give the best results for each individual mobile station.

In one embodiment of the present invention, an estimate of the doppler frequency is determined by first determining an estimate of the channel between the transmitter and the receiver. The channel is considered to be a linear transfer function with an impulse response which creates all the variations in phase and signal strength between the transmitter and the receiver. Several channel estimates are made at different times and the difference between the channel estimates is used to determine the approximate doppler frequency of the mobile station.

Brief Description of the Drawing

For a detailed description of the preferred embodiments of the present invention reference will now be made to the accompanying drawings wherein;

Figure 1 illustrates a portion of a cellular mobile radio system having cells, a mobile switching center, base stations and mobile stations.

Figure 2 is a block diagram of the relationship between the transmitter and the receiver.

Figure 3 is a block diagram of the circuit arrangement used in

the method according to the present invention.

Figure 4 is a flow chart illustrating the calculation of the doppler frequency.

Detailed Description

Figure 1 illustrates 10 cells C1-C10, in a cellular mobile radio system. Normally, a cellular mobile radio system according to the present invention would be implemented with more than 10 cells. However, for the purposes of simplicity, the present invention can be explained using the simplified representation illustrated in Figure 1.

For each cell C1-C10 there is a base station B1-B10 with the same reference number as the corresponding cell. Figure 1 illustrates the base stations as situated in the vicinity of the cell center and having omni directional antennas. The cells C1-C10 are, therefore, schematically represented as hexagons. The base stations of adjacent cells may, however, be co-located in the vicinity of the cell borders and have directional antennas as is well known to those skilled in the art. Figure 1 also illustrates 9 mobile stations M1-M9 movable within a cell and from one cell to another. In a typical cellular radio system there would normally be 9 cellular mobile stations. In fact, there are typically many times the number of mobile stations as there are base stations. However, for the purposes of explaining the invention, the reduced number of mobile stations is sufficient.

Also illustrated in Figure 1 is a mobile switching center MSC. The mobile switching center MSC illustrated in Figure 1 is connected to all 10 base stations B1-B10 by cables. The mobile switching center MSC is also connected by cables to a fixed public switching telephone network. All cables from the mobile switching center MSC to the base stations B1-B10 and cables to the fixed network are not illustrated.

In addition, to the mobile switching center MSC illustrated, there may be another mobile switching center connected by cables to base stations other than those illustrated in Figure 1. Instead of cables, other means, for example, fixed radio links may be used for connecting base stations B1-B10 to the mobile switching center MSC. The mobile switching center MSC, the base station B1-B10 and the mobile stations M1-M9 are all computer controlled. Figure 2 illustrates an overview picture of the link between a transmitter 10 and a receiver 14. In one embodiment of the present invention, the transmitter 10 is in the mobile station and the receiver 14 is located at the base station. Transmitter 10 sends a signal to the receiver 14 through a channel 12. The channel is considered to be a linear transfer function with an impulse response h(t) which creates all the variations and phase and signal strength between the transmitter and the receiver. The transmitted signal s(t) is affected by the channel impulse response h(t) to form the received signal r(t) which is fed into a channel estimator 16 which calculates a discrete approximation to h(t) called h(n). The discrete approximation h(n) is then fed into the fading frequency estimator 18 which produces an estimate of the doppler frequency for the mobile station.

Figure 3 provides a detailed description of the components contained in the fading frequency estimator 18. The fading frequency estimator circuit contains a delay circuit D for delaying a channel estimate for D samples. An arrangement 24 is used for forming the difference between two channel estimates wherein one estimate has been delayed for D samples. The result of the arrangement 24 is a signal $V_j(n)$ which is equal to the difference between two channel estimates. The circuit also contains low pass filters 26, 30 and 34 which reduce the amount of noise and modulation rests in a signal. The circuit also contains squaring circuits 28 and 32 which square the $V_j(n)$ signal and the $h_j(n)$ signal. In the alternative, magnitude calculators can be substituted for the squaring circuits 28 and 32 to calculate the amplitude of the signals. Finally, the circuit contains a comparing component for dividing two signals.

The operation of the fading frequency estimator shown in Figure 3 will be described in more detail with reference to Figure 4. When the receiver 14 receives a signal from the transmitter 10, the channel estimator 16 calculates a channel estimate of the impulse response h(t) for a time t1. The channel estimator then calculates a second channel estimate component at a time t2 which occurs D samples later in Step 52. The arrangement 24 then calculates the difference between the two channel estimate components $h_j(n)$ and $h_j(n-D)$ in Step 52. The result of the difference between the two signals is the signal $V_j(n)$. The signal $V_j(n)$ is then filtered by a low pass filter 26 to reduce the amount of noise and modulation in the signal. This is essential to getting a useful doppler frequency estimate in a noise environment. The $V_j(n)$ signal is then squared in Step 58. The square value of the signal $V_j(n)$ is then passed through a low pass filter 30 in Step 60. In the meantime, the $h_j(n)$ signal is squared in Step 62 and passed through a low pass filter 34 in Step 64. Finally, the square value of the signal $V_j(n)$ is divided by the square value of the $h_j(n)$ signal to normalize the signal in Step 56. The result is proportional to the squared value of the doppler frequency for the mobile station. As a result, the speed of the mobile station can be estimated by determining the approximate doppler frequency for the mobile station.

The present invention, as described above, determines an approximation of the doppler frequency of a mobile station. As a result, the cellular mobile radio system can use the doppler frequency or the speed of the mobile station to prioritize a handoff queue or to select an appropriate detecting algorithm. While the invention has been described in its preferred embodiments, it is to be understood that the words that have been used to words of description rather than of limitation and the changes within purview of the appended claims may be made without the party from the true scope and spirit of the invention in its broader aspects.

WE CLAIM:

1. A method for estimating the doppler frequency of the mobile station in a cellular mobile radio system having a plurality of base stations and a plurality of mobile stations comprising the steps of:

determining channel estimate components at a plurality of different times for a signal between a transmitter and a receiver to produce a first and second signal;

calculating the difference between said first and second signals to produce a third signal; and

calculating the amplitude of said third signal and said first signal.

2. A method for estimating the doppler frequency of a mobile station in a cellular mobile radio system having a plurality of base stations and a plurality of mobile stations according to claim 1, wherein said second signal is delayed for a predetermined period of time.

3. A method for estimating the doppler frequency of a mobile station in a cellular mobile radio system having a plurality of base stations and a plurality of mobile stations according to claim 1, further comprising the step of filtering said third signal to reduce noise and modulation rests.

4. A method for estimating the doppler frequency of a mobile station in a cellular mobile radio system having a plurality of base stations and a plurality of mobile stations according to claim 3, wherein said third signal is filtered by a low pass filter.

5. A method for estimating the doppler frequency of the mobile station in a cellular mobile radio system having a plurality of base stations and a plurality of mobile stations according to claim 1, wherein said third signal and said first signal are squared to calculate the amplitude of said signals.

6. A method for estimating the doppler frequency of a mobile station in a cellular mobile radio system having a plurality of base stations in a plurality of mobile stations according to claim 5, wherein said squared first signal and said squared third signal are filtered by a low pass filter.

7. A method for estimating the doppler frequency of a mobile station in a cellular mobile radio system having a plurality of base stations and a plurality of mobile stations according to claim 1, wherein the amplitude of said third signal and said first signal are calculated by a magnitude calculator.

8. A method for estimating the doppler frequency of a mobile station in a cellular mobile radio system having a plurality of base stations and a plurality of mobile stations according to claim 1, wherein said third signal is normalized by dividing said third signal by said first signal.

9. A circuit for estimating the doppler frequency of a signal between a mobile station and a base station in a cellular mobile radio system having a plurality of base stations and a plurality of mobile stations comprising:

calculating means for calculating channel estimate components for said signal between the mobile station and the base station to produce a first and second signal;

differential means for calculating the difference between said first and second signals to produce a third signal;

filtering means for filtering said third signal;

multiplying means for squaring the first signal and the third signal;

means for dividing said squared third signal by said squared first signal.

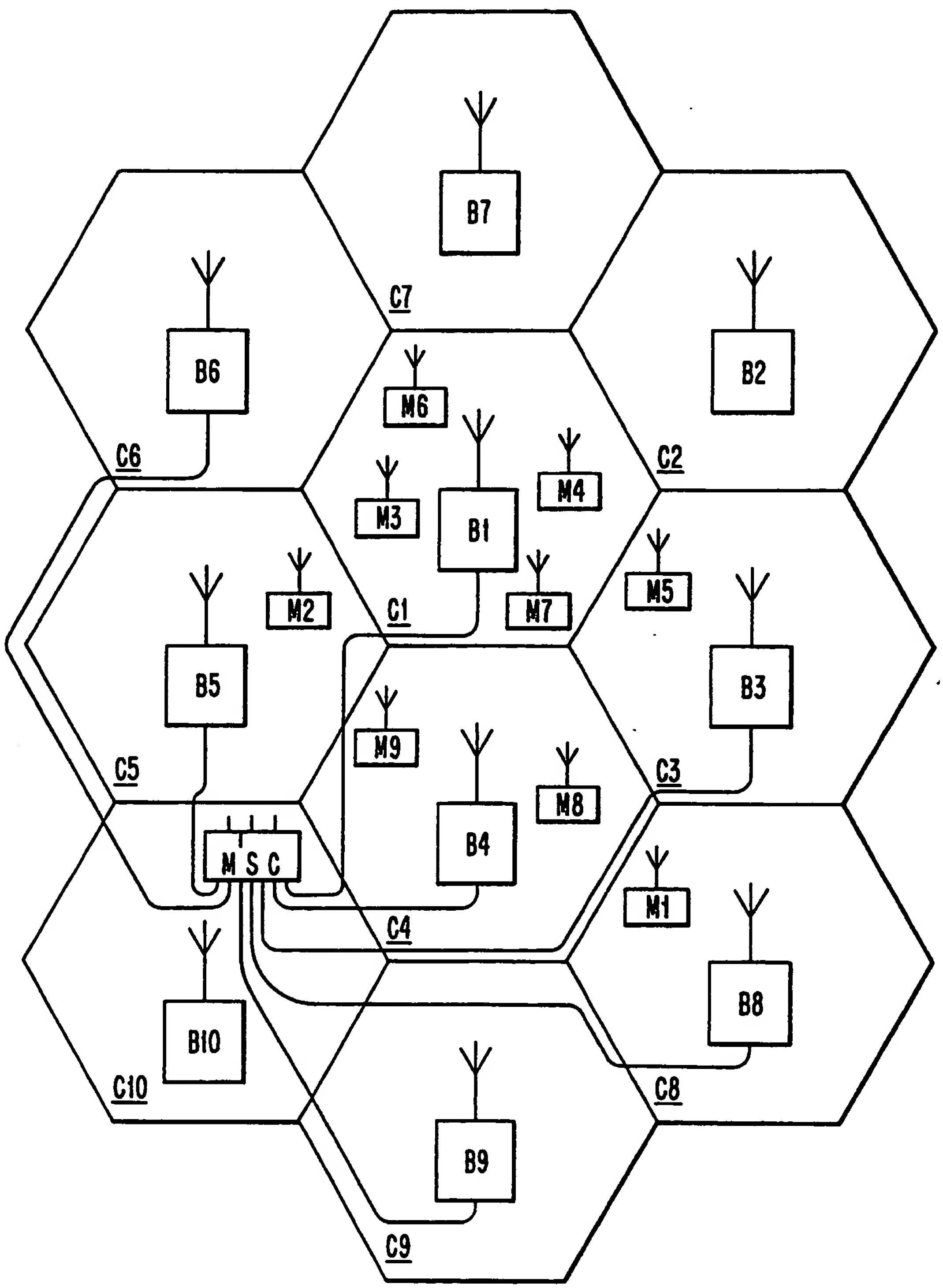
10. A circuit according to claim 9, wherein said filtering means is a low pass filter.

11. A circuit according to claim 9, further comprising a second filtering means for filtering said squared first signal and said

squared third signal.

12. A circuit according to claim 11, wherein said second filtering means is a low pass filter.

Fig.1


B7
C7
B6
B2
M6
C6
M4
C2
M3
B1
M2
M7
M5
B5
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B9
C10
C8
C9

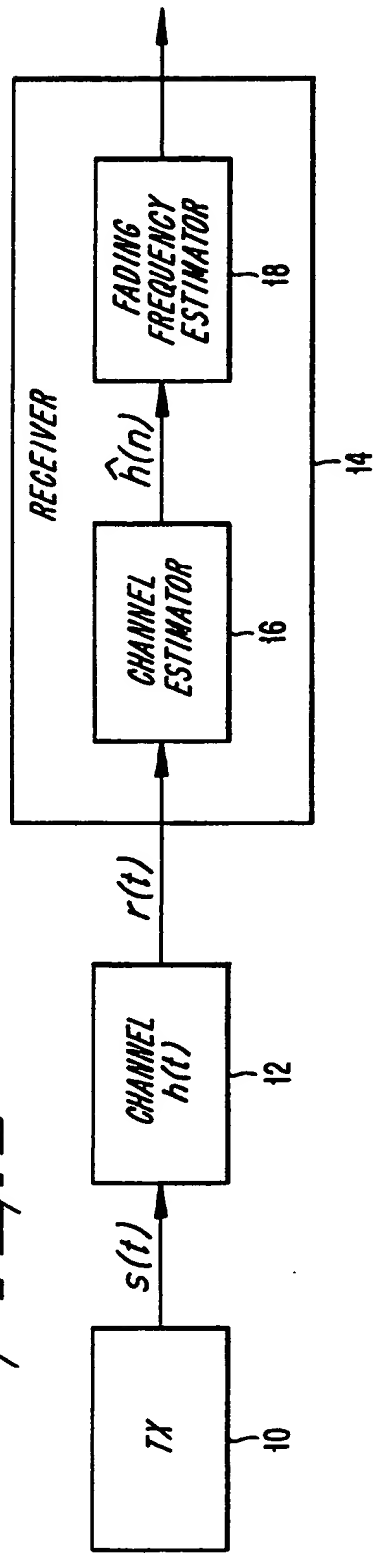

TX
10
s(t)
CHANNEL
h(t)
12
r(t)
RECEIVER
CHANNEL
ESTIMATOR
16
ĥ(n)
FADING
FREQUENCY
ESTIMATOR
18
14

FIG. 2

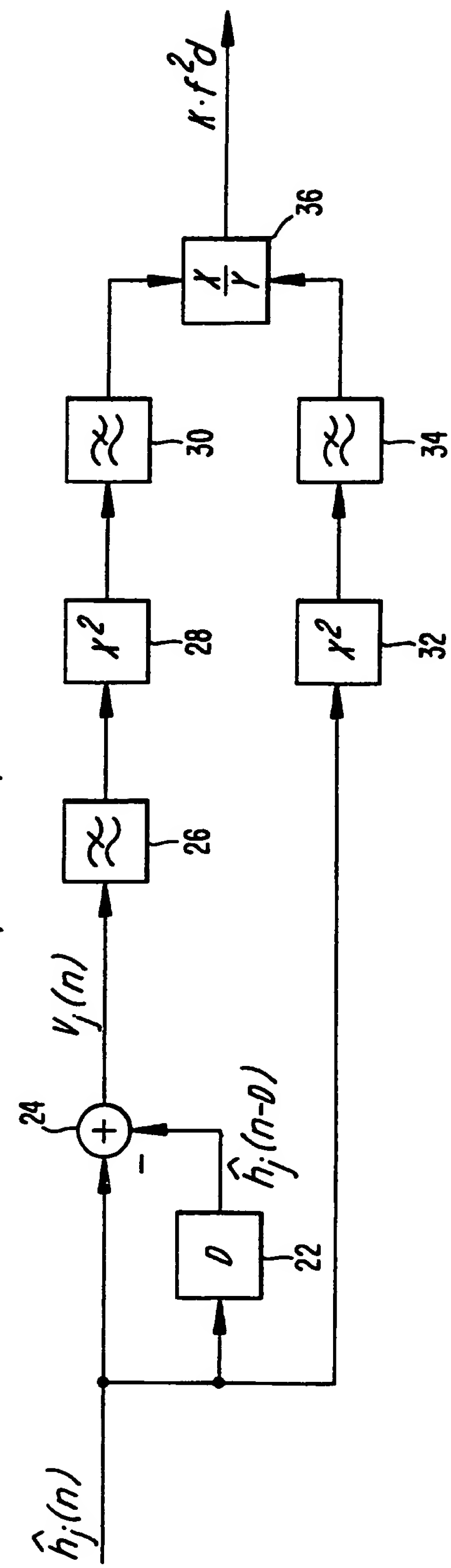
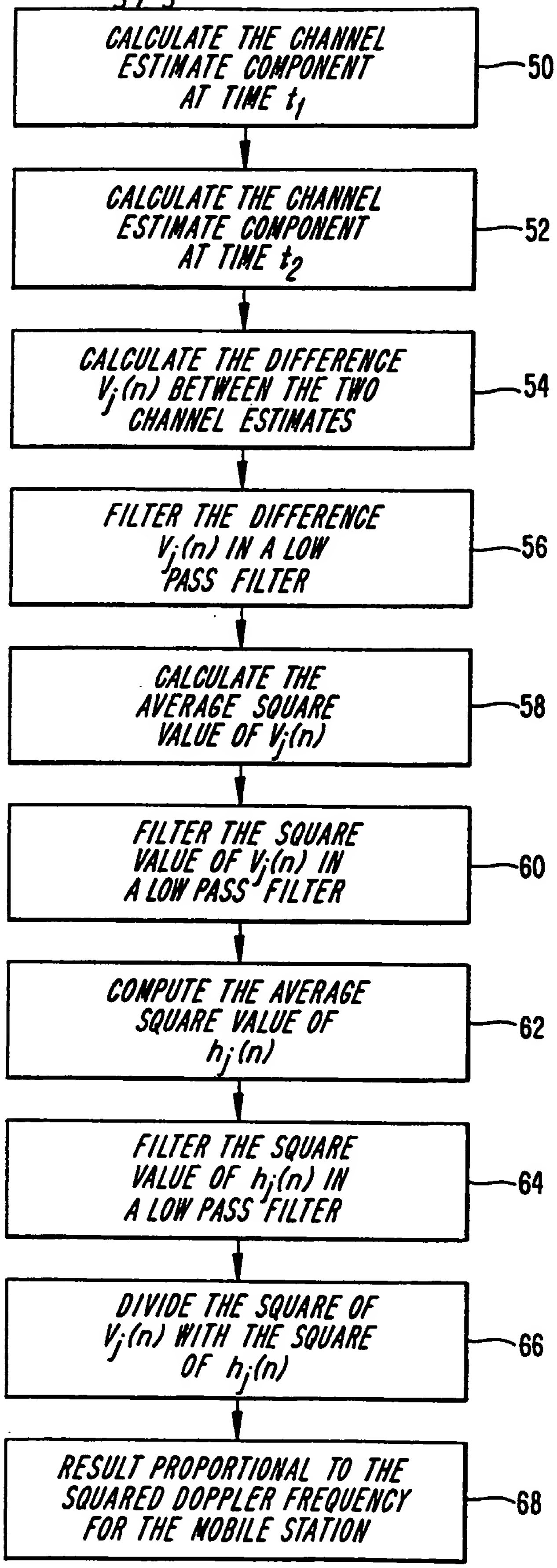

ĥj(n)
D
22
ĥj(n-D)
24
-
vj(n)
26
x²
28
30
x²
32
34
x/y
36
k·f²d

FIG. 3

Fig. 4


CALCULATE THE CHANNEL ESTIMATE COMPONENT AT TIME t_1
50
CALCULATE THE CHANNEL ESTIMATE COMPONENT AT TIME t_2
52
CALCULATE THE DIFFERENCE $V_j(n)$ BETWEEN THE TWO CHANNEL ESTIMATES
54
FILTER THE DIFFERENCE $V_j(n)$ IN A LOW PASS FILTER
56
CALCULATE THE AVERAGE SQUARE VALUE OF $V_j(n)$
58
FILTER THE SQUARE VALUE OF $V_j(n)$ IN A LOW PASS FILTER
60
COMPUTE THE AVERAGE SQUARE VALUE OF $h_j(n)$
62
FILTER THE SQUARE VALUE OF $h_j(n)$ IN A LOW PASS FILTER
64
DIVIDE THE SQUARE OF $V_j(n)$ WITH THE SQUARE OF $h_j(n)$
66
RESULT PROPORTIONAL TO THE SQUARED DOPPLER FREQUENCY FOR THE MOBILE STATION
68

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 92/00430

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: H 04 Q 7/00, G 01 S 11/10

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	H 04 B, H 04 Q, G 01 S

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
A	EP, A2, 0424704 (VAISALA OY) 2 May 1991, see abstract —	1,9
P,A	GB, A, 2240696 (NEC CORPORATION) 7 August 1991, see abstract —	1,9
P,A	WO, A2, 9201950 (BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY) 6 February 1992, see abstract —	1,9

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
25th September 1992	01 -10- 1992
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	Göran Magnusson GÖRAN MAGNUSSON

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 92/00430

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 28/08/92
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
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		CA-A-	2028576	91-04-27
		CN-A-	1051429	91-05-15
		JP-A-	3140889	91-06-14
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